A new way to measure cirrus cloud ice water content by using ice Raman scatter with Raman lidar

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[1] To improve our understanding of cirrus cloud radiative impact on the current and future climate, improved knowledge of cirrus cloud microphysical properties is needed. However, long-term studies of the problem indicate that accurate cirrus cloud measurements are challenging. This is true for both, remote sensing as well as in situ sampling. This study presents a new method to remotely sense cirrus microphysical properties utilizing the Raman scattered intensities from ice crystals using a Raman lidar. Since the intensity of Raman scattering is fundamentally proportional to the number of molecules involved, this method provides a more direct way of measuring the ice water content compared with other schemes. Case studies presented here show that this method has the potential to provide simultaneous measurements of many of the essential information of cirrus microphysical properties. *INDEX TERMS:* 0320 Atmospheric Composition and Structure: Cloud physics and chemistry; 0394 Atmospheric Composition and Structure: Instruments and techniques; 3360 Meteorology and Atmospheric Dynamics: Remote sensing. **Citation:** Wang, Z., D. N. Whiteman, B. B. Demoz, and I. Veselovskii (2004), A new way to measure cirrus cloud ice water content by using ice Raman scatter with Raman lidar, *Geophys. Res. Lett.*, *31*, L15101, doi:10.1029/2004GL020004.

1. Introduction

[2] Cirrus clouds affect the surface and top-of-atmosphere energy budgets and can produce large local variations in atmospheric heating. The degree and extent of the so-called greenhouse-versus-albedo effects involving cirrus clouds will lead to significant atmospheric differential cooling and heating in the vertical as well as on horizontal scales [*Liou*, 1986] and is dependent on cirrus microphysical properties and their vertical distribution [*Stephens et al.*, 1990]. However, it is a challenging task to measure cirrus Ice Water Content (IWC) and particle size by remote sensing or in situ sampling. IWC estimated from in situ particle size probes has large uncertainties associated with different ice crystal shapes and densities [*Heymsfield et al.*, 2002]. There have been significant advances in ground-based remote sensing of cirrus clouds using the Department of Energy Atmospheric Radiation Measurement (ARM) program Cloud and Radiation Testbed (CART) site measurements [*Mace et al.*, 1998; *Wang and Sassen*, 2002]. Nevertheless, uncertainty in the retrieved IWC by using lidar, radar, and radiometer measurements might be very large under some situations because one has to make several critical assumptions about cirrus clouds such as the size distribution and density of ice crystals, which vary a lot in cirrus clouds. A remote sensing method that possesses a signal that is directly related to IWC would be very attractive for IWC measurements and would also be of great value in studying other techniques for obtaining IWC. Here, we report on a new method to remotely measure IWC using Raman scattering from ice in cirrus clouds. First, we briefly describe our Raman lidar system. Then we present the method and measurements. Results from a lidar-radar algorithm are used to calibrate the ice Raman scatter based retrieval algorithm.

2. The GSFC Scanning Raman Lidar (SRL)

[3] The GSFC/NASA SRL uses a tripled Nd:YAG laser (355 nm) combined with two telescopes using different fields of view to measure high altitude and low altitude signals. Light backscattered by molecules and aerosols at the laser wavelength as well as Raman scattered light from water vapor (3657 cm^{-1}), liquid/solid water (3200 cm^{-1} to 3600 cm^{-1}), and nitrogen (2329 cm^{-1}) molecules is collected by a 0.76 m, f/5.2, variable field-of-view Dall-Kirkham telescope mounted horizontally on a 3.7 m optical table. This telescope is typically operated using 0.25-milliradian field of view and acquires the high altitude signals. A smaller 0.25 m telescope is mounted inside of the larger telescope and operates at ~1.0 milliradian field of view. Figure 1 presents the transmission of solid/liquid water and water vapor filters used in SRL along with the water and ice Raman scatter spectrum at the laser wavelength of 355 nm

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